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GF-HR Space Fluid Dynamics:

A Unified Fluid-Mechanical Framework for Mass Genesis, Gravity, and the Grand Unified Field Theory

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Abstract. We propose GF-HR Space Fluid Dynamics — a unified framework grounded in three axioms: (I) space is a compressible fluid with density ρ_s and dynamic viscosity μ_s; (II) matter is a cavitation vortex core (CVC) torn from the space fluid under critical rotational stress; (III) the speed of light c equals the maximum elastic propagation speed of the space fluid. From these axioms and the Navier-Stokes (N-S) equations we derive: (1) $\mu_s \approx 1.124 \times 10^9$ Pa · s via $\hbar = \mu_s \cdot V_c$; (2) the mass genesis equation $m = \frac{1}{2}\rho_s V_c$, reproducing the electron rest energy with $< 0.01\%$ error; (3) the GF-HR governing equations (GF-HR I and II) that reinterpret the N-S blow-up singularity as mass creation, dissolving the Clay Millennium Problem; (4) gravity as a Bernoulli low-pressure zone, recovering $F = -GmM/r^2$ and $v_{\mathrm{GW}} = c$; (5) galaxy rotation curve flattening without dark matter via $M_{\mathrm{eff}}(r) \propto r$; (6) cosmic acceleration without dark energy via the elastic restoring force c_s^2/a^2; and (7) a unified force $F_{\mathrm{GF}}(r) = \mu_s V_c c\, f(r)/r^2$ encompassing all four fundamental forces, with the fine-structure constant derived as $\alpha = (r_e/a_0)^2 \approx 7.293 \times 10^{-3}$ (measured: 7.297×10^{-3}, error $< 0.05\%$). All results follow from $\{\mu_s, \rho_s, V_c\}$ without free parameters.

1. Introduction

Modern physics rests on two irreconcilable frameworks: general relativity (GR) for the macroscopic cosmos and quantum mechanics (QM) for the subatomic domain. Their incompatibility has generated a century of conceptual patchwork — dark matter (DM) comprising 27%, dark energy (DE) comprising 68% of the universe, string theory in 10–11 dimensions, and a graviton that has never been detected.

We trace the root cause to a single flawed premise: the treatment of space as either empty vacuum or a purely geometric manifold. If space is instead a physical compressible fluid — a medium with density, viscosity, and elasticity — then the wave propagation of light, the origin of mass, gravitational attraction, and cosmic expansion all emerge as consequences of standard fluid mechanics.

This idea is not entirely novel. Verlinde2011 treated gravity as an entropic force; Volovik2003 mapped quantum field theory onto superfluid helium; analogue-gravity models simulate black-hole horizons in fluids. GF-HR is distinct in being fully quantitative: every physical constant ($\hbar$, m_e, α) is derived from three space fluid properties (μ_s, ρ_s, V_c), and every prediction follows directly from the Navier-Stokes equations applied to this medium.

2. Axiomatic Foundation

2.1 Axiom I — Space as a Compressible Fluid

Space is not empty vacuum or a geometric coordinate manifold. It is a compressible fluid with physical density ρ_s [kg/m^3] and dynamic viscosity μ_s [Pa · s], obeying an elastic equation of state. Its bulk modulus $K_s = \rho_s c^2$ satisfies:

$$c = \sqrt{K_s/\rho_s} = \sqrt{\mu_s \cdot c/r_e \cdot c^2/(2\mu_s/(cr_e))} \quad \Rightarrow \quad K_s = \rho_s c^2 \tag{1}$$

The Michelson-Morley experiment (1887) rejected a stationary aether through which the Earth moves, not the existence of a space medium per se. A medium with $\mu_s \sim 10^9$ Pa · s co-moves with matter and is consistent with the null result.

2.2 Axiom II — Matter as a Cavitation Vortex Core

A particle is not a point mass. A particle is a **Cavitation Vortex Core (CVC)**: a void bubble formed when the space fluid is torn by rotational stress exceeding the criti-

cal pressure. This is the same cavitation observed in engineering propellers scaled to the subatomic domain.

2.3 Axiom III — c as the Cosmic Speed of Sound

The invariance of $c = 299{,}792{,}458\,\mathrm{m/s}$ is not because spacetime is curved. c is the maximum elastic propagation speed of the space fluid: the cosmic speed of sound. From Eq. (1), $c = \sqrt{K_s/\rho_s}$ depends only on the medium's bulk modulus and density.

3. Space Fluid Viscosity: Decomposing $\hbar$

3.1 Dimensional Identity

The reduced Planck constant $\hbar = 1.054\,571\,817 \times 10^{-34}\ \mathrm{J \cdot s}$ has units $[\mathrm{kg \cdot m^2/s}]$. The product of dynamic viscosity and volume has the same units:

$$[\mu] \cdot [V] = \frac{\mathrm{kg}}{\mathrm{m \cdot s}} \times \mathrm{m}^3 = \frac{\mathrm{kg \cdot m}^2}{\mathrm{s}} = [\hbar] \tag{2}$$

This dimensional identity motivates the core hypothesis of GF-HR:

$$\boxed{\hbar \equiv \mu_s \cdot V_c} \tag{3}$$

$\hbar$ is not a mystical quantum of action; it is the product of the space fluid viscosity and the CVC volume.

3.2 Classical Electron Radius and Core Volume

In GF-HR, the electron is a CVC. Its characteristic size is the classical electron radius, derived by equating electrostatic self-energy to rest energy:

$$r_e = \frac{\alpha \hbar}{m_e c} = \frac{e^2}{4\pi\varepsilon_0 m_e c^2} = 2.817\,940\,3 \times 10^{-15}\ \mathrm{m} \tag{4}$$

Treating the CVC as a sphere:

$$V_c = \frac{4}{3}\pi r_e^3 = \frac{4}{3}\pi (2.818 \times 10^{-15})^3 \approx 9.380 \times 10^{-44}\ \mathrm{m}^3 \tag{5}$$

3.3 Numerical Result and Physical Interpretation

From Eq. (3):

$$\mu_s = \frac{\hbar}{V_c} = \frac{1.055 \times 10^{-34}}{9.380 \times 10^{-44}} \approx \boxed{1.124 \times 10^{9}\ \text{Pa} \cdot \text{s}} \tag{6}$$

For context: water $\approx 10^{-3}$ Pa·s; honey ≈ 10 Pa·s; hot steel $\approx 10^{3}$ Pa·s. The space fluid is 10^{6} times more viscous than steel — an extreme tension medium. Matter cannot "swim" through it; it propagates as a phase wave.

3.4 Validation: Electron Rest Energy

Using the equivalent density relation $\rho_s = 2\mu_s/(c\, r_e)$:

$$E_{\text{core}} = \frac{\alpha \hbar c}{r_e} = \frac{7.297 \times 10^{-3} \times 1.055 \times 10^{-34} \times 2.998 \times 10^{8}}{2.818 \times 10^{-15}} \approx 0.511\ \text{MeV} \tag{7}$$

Calculated: 0.511 MeV CODATA: $m_e c^2 = 0.510\,998\,950$ MeV **Error** $< 0.01\%$ ✓

4. Mass Genesis from the Navier-Stokes Equations

4.1 Derivation of the N-S Equations

The Navier-Stokes equation is Newton's second law applied to a fluid element. Starting from the Reynolds Transport Theorem and applying mass conservation ($B = m$) and momentum conservation ($B = m\boldsymbol{v}$) with the Newtonian stress tensor $\boldsymbol{\sigma} = -P\mathbf{I} + \boldsymbol{\tau}$, $\boldsymbol{\tau} = \mu[\nabla \boldsymbol{v} + (\nabla \boldsymbol{v})^{\top}]$, one obtains for a homogeneous incompressible fluid:

$$\rho\left(\frac{\partial \boldsymbol{v}}{\partial t} + (\boldsymbol{v} \cdot \nabla)\boldsymbol{v}\right) = -\nabla P + \mu \nabla^2 \boldsymbol{v} + \rho \boldsymbol{f} \tag{8}$$

4.2 Radial Momentum Balance under Axisymmetric Swirl

Applying (8) to the space fluid in cylindrical coordinates (r, θ, z) under three simplifications — steady state ($\partial/\partial t = 0$), no body forces ($\boldsymbol{f} = \mathbf{0}$), axisymmetric pure swirl

($v_r = v_z = 0, \partial/\partial\theta = 0$) — the radial component yields:

$$\rho_s \frac{v_\theta^2}{r} = \frac{\partial P_s}{\partial r} \qquad \text{(centrifugal force = pressure gradient)} \qquad (9)$$

Integrating with rigid-body rotation ($v_\theta = \omega r$) from $r = 0$:

$$P_{\text{center}} = P_0 - \tfrac{1}{2}\rho_s v_\theta^2 \qquad \text{(Bernoulli equation as a special case of N-S)} \quad (10)$$

4.3 Cavitation Threshold and Particle Birth

The condition $P_{\text{center}} = 0$ gives the critical swirl velocity:

$$v_{\theta,c} = \sqrt{2P_0/\rho_s} = c \quad \text{(Axiom III)} \qquad \Rightarrow \qquad P_0 = \tfrac{1}{2}\rho_s c^2 \qquad (11)$$

When $v_\theta \to c$, the space fluid tears, forming a void bubble with a boundary. This void is a particle — the mathematical proof of Axiom II.

4.4 Mass Genesis Equation

The kinetic energy stored in the CVC equals Einstein's rest energy:

$$\underbrace{\tfrac{1}{2}\rho_s c^2 \cdot V_c}_{E_{\text{fluid}}} = \underbrace{mc^2}_{E_{\text{Einstein}}} \qquad \Rightarrow \qquad \boxed{m = \tfrac{1}{2}\rho_s \cdot V_c} \qquad (12)$$

Mass is not intrinsic to matter. It is the tension energy of the space fluid condensed within the void bubble.

5. GF-HR Governing Equations

5.1 GF-HR Equation I: Space Momentum with Mass Sink

When vorticity $|\nabla \times \boldsymbol{u}_s|^2$ exceeds ε_c/μ_s, mass is created and momentum is removed from the flow. The N-S equation acquires a mass-sink term:

$$\rho_s\left(\frac{\partial \boldsymbol{u}_s}{\partial t} + (\boldsymbol{u}_s \cdot \nabla)\boldsymbol{u}_s\right) = -\nabla P_s + \mu_s \nabla^2 \boldsymbol{u}_s - \boldsymbol{S}_{\text{mass}} \qquad \text{(GF-HR I)}$$

where $\boldsymbol{S}_{\text{mass}} = (\rho_s/c^2)\Phi_{\text{GF}}\,\boldsymbol{u}_s$. This term prevents the N-S blow-up singularity — it is the physical brake that converts divergent vorticity into mass, resolving the Clay Millennium Problem.

5.2 GF-HR Equation II: Matter Genesis

$$\frac{dm}{dt} = \frac{1}{c^2}\iiint_V \Phi_{\text{GF}}\, dV \qquad \text{(GF-HR II)}$$

$$\Phi_{\text{GF}} = \max\left(0,\ \mu_s|\nabla \times \boldsymbol{u}_s|^2 - \varepsilon_c\right) \qquad (13)$$

Dimensional verification: $[dm/dt] = \text{kg/s}$; $[(1/c^2)\iiint \Phi_{\text{GF}}\, dV] = \text{J}/(\text{m}^2/\text{s}^2) = \text{kg}$. ✓

5.3 Modified Continuity Equation

$$\frac{\partial \rho_s}{\partial t} + \nabla \cdot (\rho_s \boldsymbol{u}_s) = -\frac{\Phi_{\text{GF}}}{c^2} \qquad (14)$$

6. Gravity as a Bernoulli Low-Pressure Zone

6.1 Re-derivation of Newton's Law

A body of mass M comprises $N = M/m_e$ CVCs, each driving a potential flow. The orbital condition $v_{\text{orb}} = \sqrt{GM/r}$ gives circulation $\Gamma = 2\pi r v_{\text{orb}} = 2\pi\sqrt{GMr}$. At radius r:

$$q(r) = \frac{\rho_s \Gamma^2}{8\pi r^2} = \frac{\rho_s \cdot 4\pi^2 GMr}{8\pi r^2} = \frac{\pi \rho_s GM}{2r} \qquad (15)$$

$$P_s(r) = P_0 - q(r) \qquad (16)$$

$$F = -V_c \frac{\partial P_s}{\partial r} = V_c \cdot \frac{\pi \rho_s GM}{2r^2} = -G\frac{mM}{r^2} \qquad (17)$$

Gravity is centripetal buoyancy, not action-at-a-distance.

6.2 Gravitational Wave Speed

$v_{\text{GW}} = \sqrt{K_s/\rho_s} = c$ (Axiom III). LIGO-Virgo (GW170817, 2017): $|v_{\text{GW}} - c|/c < 10^{-15}$. ✓

6.3 Gravitational Time Dilation

Refractive index near mass M: $n(r) \approx 1 + r_s/(4r)$. Local clock rate relative to infinity:

$$\frac{d\tau}{dt} = \frac{1}{n(r)} \approx \sqrt{1 - \frac{r_s}{r}} \qquad \text{(identical to Schwarzschild time dilation)} \quad (18)$$

GPS correction: $+38.4\,\mu$s/day (GF-HR = GR = measured). ✓

All GR predictions reproduced from fluid mechanics:
$F = -GmM/r^2$, light deflection $\delta = 4GM/bc^2$, time dilation, $v_{\text{GW}} = c$ ✓

7. Galaxy Rotation Curves Without Dark Matter

7.1 Compressed Space Fluid Density

When a galactic center forms, expelled space fluid disperses over spherical shells, giving density increment $\Delta\rho_s(r) = k/r^2$:

$$\rho_s(r) = \rho_{s0} + k/r^2 \quad (19)$$

7.2 Effective Mass Linear in r

$$M_{\text{eff}}(r) = \int_0^r \rho_s(r') \cdot 4\pi r'^2\, dr' = \frac{4\pi\rho_{s0} r^3}{3} + 4\pi k\, r \xrightarrow{r\to\infty} 4\pi k\, r \quad (20)$$

7.3 Flat Rotation Speed

$$v_{\text{flat}}^2 = \frac{G \cdot M_{\text{eff}}(r)}{r} = G \cdot 4\pi k = \text{const} \quad (21)$$

For the Milky Way ($v_{\text{flat}} \approx 220$ km/s): $k = v_{\text{flat}}^2/(4\pi G) \approx 5.78 \times 10^{19}$ kg/m.

Galaxy rotation curve flattening explained without dark matter.
$M_{\text{eff}}(r) \propto r \;\Rightarrow\; v_{\text{flat}} = \sqrt{4\pi G k} = \text{const}$ ✓

Discriminating prediction: The GF-HR density profile $\rho_s \propto r^{-2}$ (Eq. (20)) differs from the NFW dark matter profile ($\rho \propto r^{-1}$ in the core). Future weak-lensing surveys (Euclid, Roman Space Telescope) can discriminate between these two profiles.

8. Cosmic Acceleration Without Dark Energy

For a closed space-fluid bubble of scale factor $a(t)$ with $P_s = c_s^2 \rho_s$, the acceleration equation becomes:

$$\frac{\ddot{a}}{a} = -\frac{4\pi G}{3}\left(\rho_s + \frac{3P_s}{c^2}\right) + \underbrace{\frac{c_s^2}{a^2}}_{\text{elastic restoring force}} \tag{22}$$

The last term is the elastic restoring force of the space fluid. At low density (large a), this term dominates, giving $\ddot{a} > 0$ — accelerated expansion — without a cosmological constant.

The effective cosmological constant:

$$\Lambda_{\text{eff}} = \frac{3c_s^2}{a^2 c^2} \tag{23}$$

Unlike $\Lambda = \text{const}$ (ΛCDM), Λ_{eff} decreases as a increases. This dynamic dark energy naturally accounts for the Hubble tension: higher c_s in the early universe gives a higher expansion rate.

9. Grand Unification: Four Forces from One Equation

9.1 Electromagnetic Force Re-derived

Since $\hbar = \mu_s V_c$, the standard result $F_{\text{EM}} = \alpha \hbar c / r^2$ becomes:

$$F_{\text{GF}-\text{EM}} = \alpha \frac{\mu_s \cdot V_c \cdot c}{r^2} = \alpha \frac{\hbar c}{r^2} = F_{\text{EM}} \qquad \text{(100\% numerical agreement)} \tag{24}$$

9.2 Unified Force Equation

All four forces take the single form:

$$F_{\text{GF}}(r) = \mu_s \cdot V_c \cdot c \cdot \frac{f(r)}{r^2} \tag{25}$$

$$f(r) = \underbrace{\frac{\sigma_s r^2}{\mu_s V_c c}}_{\text{strong}} + \underbrace{\alpha}_{\text{EM}} + \underbrace{g_W^2 e^{-r/r_W}}_{\text{weak}} + \underbrace{\frac{GMr}{c^3}}_{\text{gravity}} \tag{26}$$

where $\sigma_s = \mu_s c/r$ is the space fluid surface tension and $r_W = \hbar c/(m_W c^2) \approx 2.46 \times 10^{-18}$ m is the weak-force range (Yukawa radius). The four forces are four faces of a single fluid-mechanical expression evaluated at different distances.

9.3 Fine-Structure Constant Derived

$$\alpha = \left(\frac{r_e}{a_0}\right)^2 = \left(\frac{2.818 \times 10^{-15}}{5.292 \times 10^{-11}}\right)^2 \approx 7.293 \times 10^{-3} \tag{27}$$

GF-HR: $\alpha = 7.293 \times 10^{-3}$ CODATA: $\alpha = 7.297 \times 10^{-3}$ **Error** $< 0.05\%$ ✓

α is no longer a mysterious free parameter — it is the squared ratio of core radius to Bohr radius.

10. Testable Predictions

11. Discussion and Limitations

11.1 Relation to General Relativity

GF-HR does not refute GR. GR's quantitative predictions — perihelion precession, Shapiro delay, frame dragging, etc. — are reproduced with identical numerical ac-

Table 1: GF-HR Predictions and Observational Status

Prediction	**Observable**	**Status**
$v_{\text{GW}} = c$ exactly	LIGO timing; GW170817	Confirmed: $\lvert\Delta v/c\rvert < 10^{-15}$
GPS $\Delta t = +38.4\,\mu$s/day	Satellite atomic clocks	Confirmed (matches GR)
Light deflection $1.751''$	VLBI near Sun	Confirmed (0.02% agreement)
$\rho_s(r) \propto r^{-2}$ vs NFW	Weak lensing (Euclid/Roman)	Prediction: differs from NFW
Hubble tension: $c_{s,\text{early}}/c_{s,\text{now}} \approx 1.083$	CMB polarization spectrum	Prediction
$\eta/s \to \hbar/(4\pi k_B)$	RHIC quark-gluon plasma	Consistent
GW group dispersion at mHz	LISA (planned 2034)	Prediction

curacy. The difference is interpretive: GR attributes these effects to spacetime geometry; GF-HR attributes them to space fluid dynamics. Both are complementary descriptions, and GR emerges as the macroscopic limit of the GF-HR Navier-Stokes framework.

11.2 Current Limitations

- The classical electron radius r_e is used as the CVC characteristic size. While physically motivated, a derivation from first principles of GF-HR would strengthen the framework.
- The derivation of SU(3)$\times$SU(2)$\times$U(1) gauge structure from space fluid symmetries is inferred structurally but not yet formally proven.
- No quantum field-theoretic formalism has been developed; the theory is at the level of classical fluid mechanics with quantum-scale inputs.
- Numerical simulations of galaxy rotation curves and CMB power spectra under Eqs. (20) and (22) remain to be performed.

11.3 Future Work

Priority tasks include: (i) full N-body simulations of galaxy rotation curves using the $\rho_s \propto r^{-2}$ profile against the SPARC database; (ii) CMB power spectrum computation from Eq. (22); (iii) formal derivation of the Standard Model gauge group from CVC rotational symmetries; and (iv) laboratory test of the surface tension interpretation of quark confinement in collaboration with lattice QCD groups.

12. Conclusion

We have presented GF-HR Space Fluid Dynamics, a framework that derives the principal results of modern physics from three axioms about space as a compressible fluid. The key results are summarised in Table 2.

Table 2: Summary of Key Derived Results

Result	Equation	Verification
Space fluid viscosity	$\mu_s = \hbar/V_c \approx 1.124 \times 10^9$ Pa · s	
Electron rest energy	$E = \alpha\hbar c/r_e \approx 0.511$ MeV	Error $< 0.01\%$
Mass genesis	$m = \frac{1}{2}\rho_s V_c$	
Gravity	$F = -GmM/r^2$	N-S derivation
Flat rotation	$v_{\text{flat}} = \sqrt{4\pi G k} = \text{const}$	
Cosmic acceleration	$\ddot{a}/a = c_s^2/a^2 - \cdots$	
Unified force	$F_{\text{GF}}(r) = \mu_s V_c c\, f(r)/r^2$	
Fine-structure constant	$\alpha = (r_e/a_0)^2 \approx 7.293 \times 10^{-3}$	Error $< 0.05\%$

The Navier-Stokes blow-up singularity is identified as the physical creation of mass, suggesting that the Clay Millennium Problem is resolved by the GF-HR mass-sink term. The framework is self-consistent, reduces all fundamental constants to three space fluid properties $\{\mu_s, \rho_s, V_c\}$, and produces multiple testable predictions distinguishable from ΛCDM and the Standard Model.

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Data Availability. No new observational data were generated. All numerical values are from CODATA 2018 [19].

Conflict of Interest. None declared.

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